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Analytical solutions and estimates for microlevel flows

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Abstract

Steady, two-dimensional, viscous, fully developed, laminar flows are studied by the methods of isoperimetric estimations, complex analysis, and asymptotic approximations. The Carman-Kozeny averaging of velocity over the cross-sectional area of a tube is shown to become meaningless for some fractures deviating from "normal" convex shapes. Permeability of constituting tubes is estimated from above and below using a novel characteristic, the momentum of the flow domain about its boundary. Poiseuille-type flows in double-connected and misconnected domains are discussed. Longitudinal and transversal flows through a nonplanar zigzag fracture composed of annular segments are studied by an asymptotic solution of the Poisson equation and an exact solution of the Navier-Stokes equation, correspondingly. The lubrication theory approximation is compared with the case of a nonparabolic velocity profile within the fracture. The influence of tortuosity on permeability is established by calculation of the flux ratio through curved and planar fractures. For the Stokes approximation, a double-periodic combination of plane fractures and circular enlargements is studied using the Rayleigh solution and its generalization. A two-dimensional Darcian flow through a system with regular square occlusions is studied and kinematic channeling is quantified by the travel time along the fastest streamline.

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